DURIP Final Report

A Hardware-in-the-Loop Experiment and Simulation Facility for Vision-Based Control of Micro-Air-Vehicles

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14. ABSTRACT

This report documents research performed under the contract entitled "A Hardware-in-the-Loop Experiment and Simulation Facility for Vision-Based Control of Micro-Air-Vehicles (MAVs)." This experimental facility is comprised of two major components - a wind tunnel facility and a real-time virtual image generation system. Collectively, these two components form a unique closed-loop test for studying vision-based control of autonomous flight vehicles. The most important milestone achieved last year was the design and construction of the new visualization laboratory. This laboratory is equipped to display virtual environments for MAV flight simulations. Currently, a University of Florid campus database, developed by the UF Digital Worlds Institute, is being used as the virtual environment for studying vision-based control of MAVs in urban environments. This report provides a description of the new visualization laboratory and the virtual UF campus database.

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1 Introduction

This report documents research performed under the contract entitled "A Hardware-in-the-Loop Experiment and Simulation Facility for Vision-Based Control of Micro-Air-Vehicles (MAVs)." This experimental facility is comprised of two major components - a wind tunnel facility and a real-time virtual image generation system. Collectively, these two components form a unique closed-loop test facility for studying vision-based control of autonomous flight vehicles.

The most important milestone achieved last year was the design and construction of the new visualization laboratory. This laboratory is equipped to display virtual environments for MAV flight simulations. Currently, a University of Florida campus database, developed by the UF Digital Worlds Institute, is being used as the virtual environment for studying vision-based control of MAVs in urban environments. This report provides a description of the new visualization laboratory and the virtual UF campus database.

Additionally, the project achieved capabilities for hardware in the loop simulation (HILS). The visualization laboratory was augmented with a wind tunnel through interface instrumentation. This instrumentation allows a aerodynamic data, such as forces and moments measured on a MAV mounted in the tunnel, to be used in simulating flight through the virtual environment. The combination of theoretical modeling and experimental measuring provides a powerful utility for realistic simulations.

2 Year 1 Progress

2.1 Visualization Laboratory

The visualization facility consists of a virtual environment displayed on three rear-projected video screens. The UF Digital Worlds Institute, headed by Dr. James Oliverio and Dr. Andy Quay, designed and built most of the hardware system for the virtual environment. The virtual environment software is built upon MultiGen-Paradigm's distributed VEGA, which enables the loading of urban databases and synchronizes the three video screens driven by a PC image cluster. The three-screen display system is depicted in Figure (1).

Figure 1: The rear-projected display system in the visualization laboratory.

The following items were purchased in constructing the visualization laboratory:

- 12 PowerMac G5 computers (2 GHz processor)
- Server for the G5 cluster
- 2 Dell Optiplex computers (Pentium 4, 3 GHz processor
- 11 Dell workstations
- 13 NVidia Quadro FX 3000 video cards
- MultiGen Paradigm 3 year educational site license
- Multimedia (DVD and VCR)
- 1 Digital Camera
- Video Switcher
- Projection system
- Miscellaneous cabling and adapters
- Laboratory infrastructure: cabinets, carpeting, etc.

A schematic layout of the visualization laboratory is given in Figure (2). The figure shows the interconnection between the image generation system with rear-projection display and the vision processing and flight control system. Also shown is the mounting of the MAV with digital camera in front of the display screen.

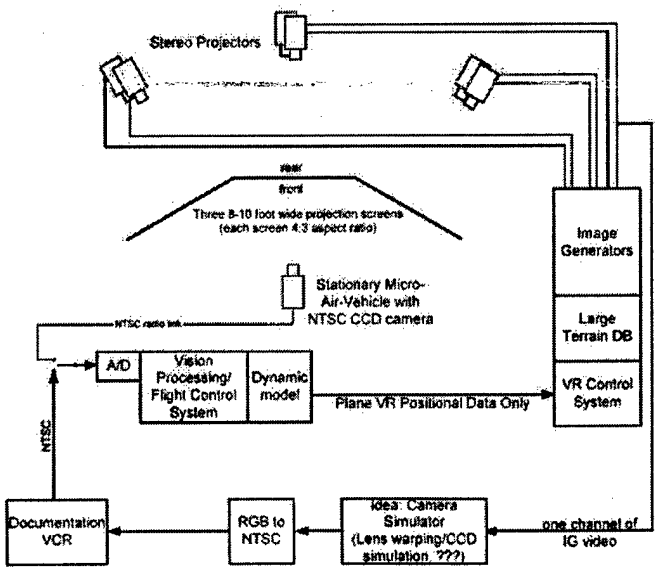

Figure 2: Conceptual layout of the visualization facility.

Finally, the software architecture of the visualization facility is depicted in Figure (3). The interrelationships of the various elements associated with displaying a virtual environment are shown in the figure. Basically, an urban database is stored and rendered according to the position of the MAV in the virtual environment. This is accomplished using the MultiGen software which also incorporates any special effects such as reflections and shadowing. The distributed rendering utilities ensure that the three displays are synchronized since individual views are typically rendered at different rates.

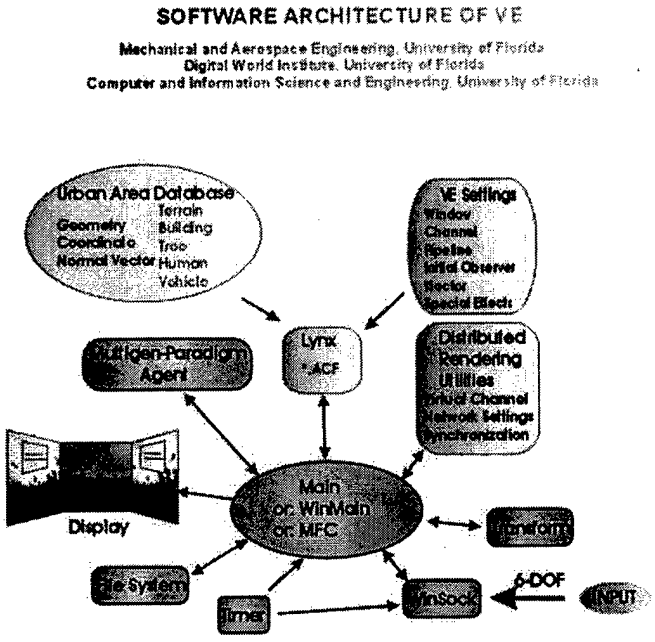

Figure 3: Software architecture of the visualization facility.

2.2 Virtual Environment Database

The visualization laboratory currently displays a UF campus database that was developed by the Digital Worlds Institute. This database contains high-resolution imagery of the exteriors of most of the buildings on the UF campus and will serve as the main virtual environment for testing vision-based control algorithms for MAVs. In the future, the database will be updated to provide more exterior details as well as views of some building interiors. The UF campus database, displayed in the Research, Education and Visualization Environment (REVE) at the Digital Worlds Institute, is shown on the right in Figure (4).

It should be noted that the visualization facility currently has the ability to display three camera views. These can be continuous views such that the three-screen display shows one panoramic image, as illustrated in Figures (1) and (4). Alternatively, they can be completely separate views as might be seen from 3 different MAVs in the environment. Figure (5) illustrates two virtual images from a single camera view during a simulated MAV flight through the campus database.

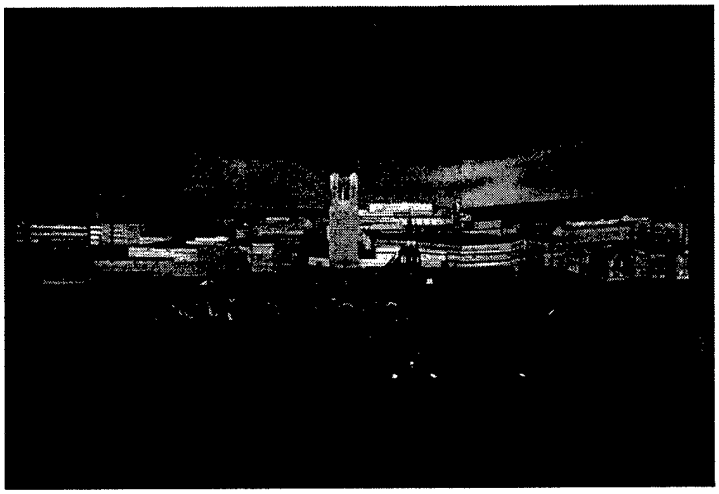

Figure 4: UF campus database displayed in the REVE at the UF Digital Worlds Institute.

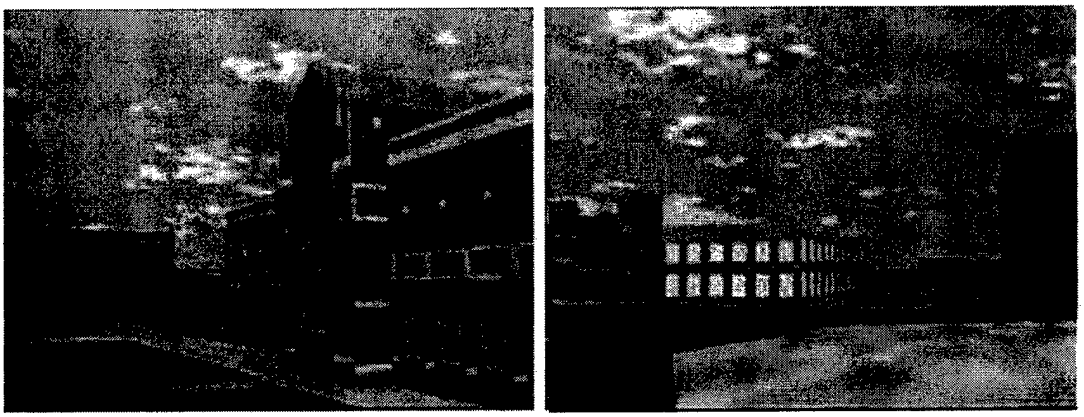

Figure 5: Virtual images from a simulated MAV flight through the UF campus database.

2.3 Interface

Over the past one and a half years the University of Florida has made great strides in modernizing the wind tunnel facilities to perform experiments on micro air vehicles. The current facility is an open loop tunnel that has a 3 foot by 3 foot test-section and limited airspeed (up to 30 miles/hour). In March, a new tunnel will be installed having two test-sections, a 2 foot by 2 foot test section and a 3 foot by 3 foot test-section. In the smaller test section, air speeds up to 200 miles per hour will be possible.

A great deal of effort has been spent on instrumentation and data acquisition and evaluating new instrumentation. Photographs of the tunnel are provided in Figure 6 and 7.

- The *visual image correlation* (VIC) system measures the deformed shapes of our flexible wings in the wind tunnel. The system has been used to document the displacements and strains on a full-field basis on our flexible wings. It has also been used to document the deformed shapes of morphed wing aircraft in situ. The VIC system combined with the wind tunnel is a unique facility. It is believed to be the only one of its kind in the world.

- The *dynamic pitch mechanism* replaces the typical sting balance mount. It is capable of pitching

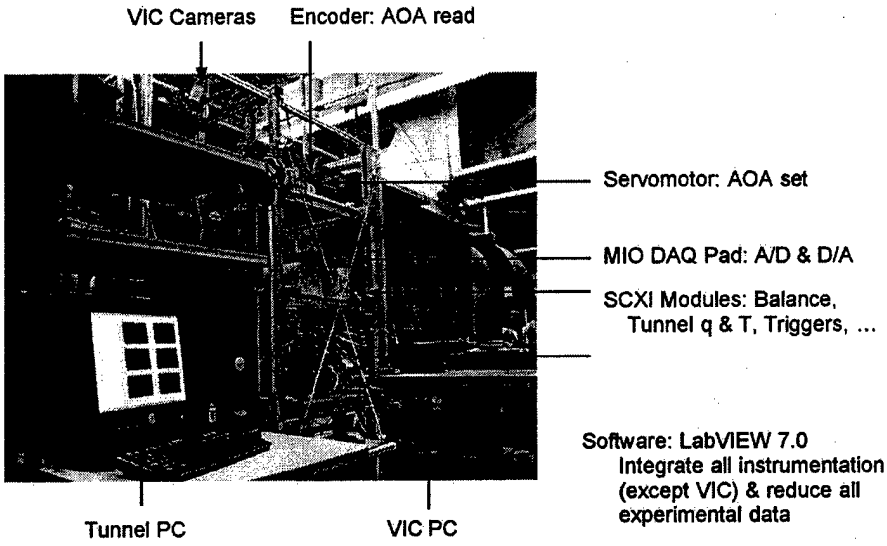

Figure 6: Wind tunnel and instrumentation.

the MAV or wing without moving vertically in the tunnel. It rotates the MAV about its center of gravity. It is capable of 2 Hertz at 45 degree amplitude.

- The *dynamic gust mechanism* is built into the current wind tunnel and is capable of producing pulsating flow up to 5 Hertz with amplitude on the order to 30% of mean airspeed. This device is used to simulate head-on wind gusts. We use the results to tune the adaptive washout mechanism on our wings.

- The *small sting balance* was purchased and installed for MAV testing. The balance is the smallest commercially available model from Aerlabs Inc.. It is capable of measurements of force on the order of 1 gram in all directions. It has enough resolution to characterize vehicles on the order to 6 inches and larger.

- The *particle image velocimetry system* is operational in the current wind tunnel. Although this piece of equipment was available prior to our focus on MAVs, it is operational and we plan to use it for flow documentation.

- The *data acquisition and automation system* from National Instruments has been installed in the tunnel. The dynamic pitch mechanism and sting balance are currently automated to sweep through the angle of attack range. Aircraft system ID has been performed on a number of vehicles including those that have autopilots.

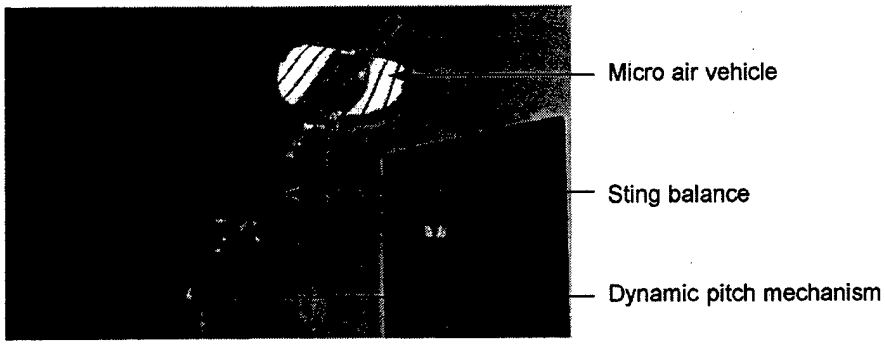

Figure 7: Sting balance and dynamic pitch mechanism.

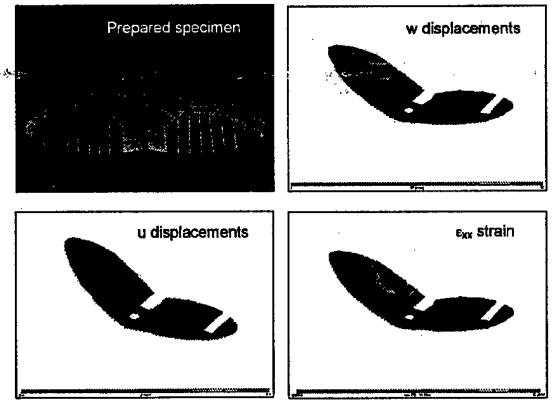

Figure 8: Deformed wing in the wind tunnel using VIC system.